Progress Report No. 11

"A Theoretical and Experimental Study of the Ionosphere Using Radio Signals from Earth Satellites"

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The Electrical Engineering Research Laboratory

University of Illinois

with the cooperation of the

University of Illinois Observatory

Urbana, Illinois

Introduction

This report describes the continuation of research on the morphology of the ionosphere, using as the general method the observation of perturbations induced by the ionosphere on radio signals from earth satellites. The program has been underway since the early part of 1958, having been instituted with the launching of the first artificial satellite, Sputnik I. The principal subjects for this research are the investigation of small scale ionospheric irregularities by means of scintillation of radio signals from satellites and the investigation of the total electron content of the ionosphere by observation of the Faraday rotation of the planes of polarization of radio signals from satellites. The chief satellites of interest during the covered period were 1961 Omicron (Transit 4A), BE-B (1964 61 A, Explorer 22, S-66), BE-C and OGO-1 (1964 54A). In addition, theoretical studies have been undertaken concerning the phenomena under experimental investigation.

Field Operations

All four field stations were in operation during the reported period. Their methods of recording are shown in Table 1. Briefly, Houghton, Baker Lake and Adak stations recorded only amplitudes for Faraday and scintillation studies, and Urbana station recorded both amplitudes and Doppler shifts.

Houghton station was originally recording the signal strength on magnetic tapes which were later transcribed on paper charts. This was found to be time consuming and inconvenient. Hence a new paper recorder was sent there, and it has been operating successfully ever since.

Table 1. Field Operations of Various Stations

Urbana	BE-B 20, 40 41, 360 Amplitude Doppler	BE-C 20, 40 41, 360 Amplitude Doppler	OGO-A 40 ± 200 kc 360 ± 200 kc Amplitude Doppler
Houghton	40, 41 Amplitude	---	---
Baker Lake	40, 41 Amplitude	---	---
Adak	40, 41 Amplitude	---	---

Data Analysis

Faraday rotation analysis of 1961 Omicron was finished. This provides us with electron content data for the period extending from June, 1961 to September, 1964. It is planned to study the diurnal, seasonal and sunspot cycle dependence of the electron content and the slab thickness. The latter is directly proportional to the temperature at the F2 peak.

Scintillation indices for November, 1964 recorded at Adak, Alaska and Wellington, New Zealand on 40 mc/s were used for magnetic conjugate correlation studies. The results are shown in Table 2. Past experience indicates that scintillation activities change fairly rapidly in time. Hence only satellite passes occurring within about two hours at Wellington and Adak are correlated. In most cases the time difference is only one-half hour. This restriction reduces the number of points, and consequently the statistics may be very rough.

The scintillation observations are divided into day and night. Unweighted correlation coefficients are computed for scintillation indices averaged over entire passes for the two stations. These coefficients should be compared with the coefficients computed for scintillation indices at conjugate L-shell values. It is seen from Table 2 that in daytime the correlation coefficient is decreased from 0.54 to 0.08 while at night it is increased from 0.36 to 0.51. This indicates perhaps that the Earth magnetic field plays a role in scintillation at night but not in daytime. It should be emphasized that the conclusion is drawn only from one month of data and hence very tentative. It seems worthwhile to pursue this matter further when more data become available.

Table 2. Correlation Coefficients of Scintillation Indices Observed at Adak and Wellington on 40 mc/s Transmitted by S-66 in November, 1964.

	Average Scintillation	L-shell Weighted Scintillation
Day (0600 - 1800)	0.54	0.08
Nighttime (1800 - 0600)	0.36	0.51

Records of signals from BE-B, BE-C and OGO-A are being analyzed. Mr. Carl Stubenrauch has rejoined the group for the summer in an effort to streamline and to computerize the data analysis procedure.

Theoretical Studies

In connection with the study of wave propagation there were two reports published during the report period. They are (1) Diffraction of Random Waves in a Homogeneous Anisotropic Medium and (2) Parameter Dependence of Phase and Log Amplitude Scintillation. The former has been accepted for presentation at the AGARD 10th symposium on "Propagation Factors in Space Communications" to be held in Rome, September 21-25, 1965.

The study of ion-exosphere is carried out with Dr. J. E. C. Gliddon. A paper entitled "A Steady State Fluid Model of the Ion-Exosphere" has been accepted for presentation at the Fifth Western National Meeting of the American Geophysical Union in Dallas, Texas, September 1-3, 1965. The report on the work is being prepared. The scope of the work is outlined in the abstract of the above paper. It is reproduced below:

> An ion-exosphere can be defined as the upper most part of the ionosphere in which the self-collision time is much larger than the time required for ions to travel between mirroring points. In such a case the system is entirely controlled by the externally applied forces and the long range Coulomb forces. If we assume that among these forces the Lorentz force is dominant and that the heat transport is negligible, a closed system of hydromagnetic equations can be derived by taking successive moments of the Vlasov equation. This system of equations is often referred to as the CGL theory or the double adiabatic theory.
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> The present investigation is concerned with the magnetohydrostatic solution of the CGL equations. The dilute plasma is assumed to be in a gravitational field, permeated by a strong dipole magnetic field and rotating at a constant angular velocity about its axis. These equations are solved in the dipole coordinate system by assuming that at the base of the ion-exosphere the collisions are frequent enough so as to make the pressure isotropic. Analytic expressions for the density, the elements in the pressure tensor, and the temperature of the fluid have been derived. A formula for the ring current has also been found. Some representative curves will be shown.

Publications

The following publications appeared during the report period.

P. R. Kranz and K. C. Yeh, "Scintillation Observations of Satellite Signals," EERL Technical Report, January, 1965, Accepted for publication by Journal of Atmospheric and Terrestrial Physics.

K. C. Yeh, "Diffraction of Random Waves in a Homogeneous Anisotropic Medium," EERL Technical Report, April, 1965.

J. F. Phelan and K. C. Yeh, "Parameter Dependence of Phase and Log Amplitude Scintillation," EERL Technical Report, June 30, 1965.

Personnel

The following persons were involved in project activities during the report period.

Dr. G. W. Swenson, Jr.	Principal Investigator	on leave
Dr. K. C. Yeh	Co-Investigator	3/4 time
Dr. James F. Phelan	Research Associate	1/4 time
Dr. Daniel B. Hodge	Visiting Assistant Professor	1/2 time
Dr. C. H. Liu	Research Associate	Full time beginning June 15, 1965
Bernard Flaherty	Electronic Engineer	Full time
Anthony Szelpal	Electronic Technician	Full time
Carl Stubenrauch	Research Assistant	Full time beginning June 15, 1965 for summer only
Paul R. Kranz	Research Assistant	1/2 time Resigned 2/64
Chyang Hsieh	Research Assistant	1/2 time
Dale M. Simonich	Research Assistant	1/2 time
Andrew P. Weise	Research Assistant	1/2 time
Wilbur L. Allain	Research Assistant	1/2 time

Several hourly student assistants have also been employed.